



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁶ : H04Q 11/04, H04J 3/06</p>	<p>A1</p>	<p>(11) International Publication Number: WO 95/22233</p> <p>(43) International Publication Date: 17 August 1995 (17.08.95)</p>						
<p>(21) International Application Number: PCT/CA95/00062</p> <p>(22) International Filing Date: 10 February 1995 (10.02.95)</p> <p>(30) Priority Data:</p> <table border="0"> <tr> <td>9402638.2</td> <td>11 February 1994 (11.02.94)</td> <td>GB</td> </tr> <tr> <td>9402770.3</td> <td>14 February 1994 (14.02.94)</td> <td>GB</td> </tr> </table> <p>(71) Applicant (for all designated States except US): NEWBRIDGE NETWORKS CORPORATION [CA/CA]; 600 March Road, P.O. Box 13600, Kanata, Ontario K2K 2E6 (CA).</p> <p>(72) Inventor; and</p> <p>(75) Inventor/Applicant (for US only): BESSETTE, Francois [CA/CA]; 24 Poullart Street, Gatineau, Quebec J8V 2C6 (CA).</p> <p>(74) Agent: MITCHELL, Richard, J.; Marks & Clerk, P.O. Box 957, Station B, Ottawa, Ontario K1P 5S7 (CA).</p>		9402638.2	11 February 1994 (11.02.94)	GB	9402770.3	14 February 1994 (14.02.94)	GB	<p>(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).</p> <p>Published</p> <p><i>With international search report.</i></p> <p><i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>
9402638.2	11 February 1994 (11.02.94)	GB						
9402770.3	14 February 1994 (14.02.94)	GB						
<p>(54) Title: METHOD OF DYNAMICALLY COMPENSATING FOR VARIABLE TRANSMISSION DELAYS IN PACKET NETWORKS</p> <div data-bbox="516 1140 1263 1728"> <pre> graph TD IP[INCOMING PACKETS] --> VDU[20 VARIABLE DELAY UNIT] VDU --> SPB[21 SPEECH PLAY-OUT BUFFER] PA[24 PACKET ANALYZER] --> CU[25 CONTROL UNIT] FLM[26 FILL LEVEL MONITOR] --> CU SPB --> FLM CU --> VDU CU --> SR[22 SPEECH RECONSTITUTER] SPB --> SR SR -- "SPEECH SAMPLES" --> DAC[23 D-T0-A CONVERTER] DAC --> A[ANALOG] </pre> </div>								
<p>(57) Abstract</p> <p>A method is described for playing out packets, such as voice or video packets, received through a packet network subject to variable transmission delays. The incoming packets are received in a delay buffer and a predetermined delay applied to the first packet of a sequence of packets. A variable delay is applied to subsequent packets to produce an appropriate constant play-out rate to reproduce the desired output. The fill level of the delay buffer is monitored and the predetermined delay applied to the first packet of a following sequence of packets adjusted to maintain the fill level within desired limits to minimize the risk of said buffer underflowing or overflowing.</p>								

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgyzstan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

- 1 -

METHOD OF DYNAMICALLY COMPENSATING FOR VARIABLE
TRANSMISSION DELAYS IN PACKET NETWORKS

This invention relates to a method and apparatus for dynamically compensating for variable transmission delays in packet networks, particularly voice networks, but the invention is also applicable to other networks, such as video networks. The invention is applicable in all integrated packet networks where voice or video may be carried including, for example, frame relay networks, ATM networks, PCME (packet circuit multiplication equipment), and LANs.

In this specification, reference is made throughout to "voice" packets, since this is the term normally used in the art to describe such networks, although it will be realized by one skilled in the art that such networks extend to any network capable of transmitting any form of audio whether it actually be voice or other form of reproducible sound.

Two methods have been proposed to compensate for variable transmission delays in packet voice networks.

In the first method, known as timestamping, which is used in ITU standard G.764, the accumulated variable transmission delay experienced by a voice packet is recorded in a timestamp field in the packet. Each intermediate node recognizes voice packets and adds to the timestamp field the amount of time that it took for the packet to transit the node. The receiver uses the value in the timestamp field to determine when to play-out the voice packet. Voice packets that experience little delay in the network will be delayed in the receiver longer before being played-out, and voice packets that experienced long network delays will be delayed less in the receiver. The effect is that the sum of the network delay and the delay in the receiver will

- 2 -

be nearly constant for all voice packets and the voice will be played-out at a uniform rate.

The disadvantage of this method is that intermediate nodes must recognize voice packets and carry out special processing. This makes this method incompatible with existing networks that do not support this function. Another disadvantage is that prior knowledge of the maximum expected delay variation is necessary.

In the second method, known as the blind delay method, a fixed delay is always added at the receiver to the first packet of a talk sequence. The delay corresponds to the maximum variable delay expected from the network. This way, if the first packet experiences minimum delay, the system compensates by adding enough delay to make sure other packets, which experience more delay, arrive before their scheduled play-out time.

The disadvantage of this method is that it may increase the delay in the voice path beyond the optimal value. This is because if first packet has already experienced the worst case delay, the delay added will include the worst case twice. Large delays degrade the system performance (or may cause the system not to meet the international standards for network delays specified in ITU-T Recommendation G.114). Delay is of special concern when speech and facsimile demodulated traffic are mixed on the same transmission facility. Another disadvantage is that prior knowledge of the maximum expected delay variation is necessary.

According to the present invention there is provided a method of playing out packets received through a packet network subject to variable transmission delays, comprising the steps of receiving incoming packets in a buffer; applying a delay to the first packet of a sequence of packets; applying a variable delay to subsequent packets of the sequence to produce an

- 3 -

appropriate constant play-out rate to reproduce the desired output; monitoring utilization of said buffer; and adjusting the delay applied to the first packet of a following sequence of packets to maintain said
5 utilization within desired limits to minimize the risk of said buffer underflowing or overflowing.

The utilization monitored can be, for example, the buffer fill level or the dwell time of packets in the buffer. Alternatively, the arrival rate of the packets
10 could be monitored.

The packets may, for example, be voice packets or video packets.

The invention (Adaptive Delay Equalization) thus uses an adaptive method to determine when to play-out
15 received packets. This method minimizes the delay applied to received packets. In a preferred embodiment, the receiver starts by applying a pre-determined delay to the first packet of a talk-spurt. The receiver delays subsequent packets by an amount appropriate to produce a
20 constant gap-free play-out rate. If the minimum number of packets in the buffer is large (i.e., the buffer is never close of under-flowing), the system slowly reduces the predetermined delay, known as the build-out delay. If packets arrive late, the build-out delay is increased in
25 order to minimize packet loss. The build-out delay adjustment can be done during speech silence. The duration of gaps between spoken words is precisely replicated by sending a 'silence duration' value in the first packet of each new talk spurt.

30 This method has the advantage that it minimizes the delay when the network is not congested, adapts itself to operate optimally in various network conditions, without any user reconfiguration, and it does not require any

- 4 -

complicated and specialized node handling of voice packets (e.g. time-stamping).

The invention also provides an apparatus for playing out packets received through a packet network subject to variable transmission delays, comprising a buffer for receiving incoming packets; a speech reconstituter for receiving said packets from said buffer and reconstituting speech samples therefrom; a variable delay unit for applying a delay to the incoming packets; a control unit for controlling said delay to apply a first delay to an incoming sequence of packets and a variable delay to subsequent packets of the sequence so as to produce an appropriate constant play-out rate to said buffer; means for monitoring the utilization of said buffer; and means for adjusting said first delay applied to the packets of a following sequence of packets to maintain said fill level within desired limits to minimize the risk of said buffer underflowing or overflowing.

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic diagram showing a variable transmission delay packet voice network ;

Figure 2 is a timing diagram of a packetized voice transmission system in accordance with the invention; and

Figure 3 is a block diagram of a variable delay compensation apparatus in accordance with the invention.

As shown in Figure 1, a speech input is transmitted in packetized form through a packet network 2, for example an ATM or Frame Relay network, which introduces a variable delay during transmission through the network.

- 5 -

The incoming packets are received by receiver 3, which outputs a re-assembled speech signal.

The packet network 2 introduces a variable propagation delay Δ . Receiver 3 introduces a further delay δ in the manner to be described.

Referring now to Figure 2, input speech consists of spurts 4 separated by periods of silence 5. Each spurt 4 is represented by a sequence of packets 6, which when they are transmitted are separated by fixed spaces 7 as shown at line 8. However, after transmission through the network the packets are no longer equally spaced, as shown at line 9, due to the variable propagation delays in the network. In accordance with the invention, as shown at line 10, the first packet 6a of each sequence is subjected to a predetermined delay, which is estimated to be adequate to avoid buffer underflow and overflow. The remaining packets of the sequence are subjected to variable delays to maintain the appropriate constant output 11. This is then decoded to reproduce the initial speech as shown at line 12.

Referring now to Figure 3, the incoming speech packets 6 are fed to variable delay unit 20, which introduces a variable delay between the packets. The output of variable delay unit 20 is fed to speech play-out buffer 21, which outputs the speech packets to speech reconstituter 22, which turns the speech packets into constant rate speech samples, normally at 8KHz. These speech samples are then converted into analog speech signals in digital-to-analog converter 23.

Incoming speech packets 6 are also fed to packet analyzer 24 whose function is to identify the start of a speech spurt and trigger control unit 25, which sets the delay introduced by the variable delay unit 20 so as to produce a constant output rate. Buffer fill level

- 6 -

monitor 26 monitors the fill level of speech play-out buffer 21. Depending on the fill level of buffer 21, control unit 25 varies the initial delay for the start of the next talk spurt. Monitor 26 can be replaced by a similar unit monitoring the dwell time of the packets in the buffer. Alternatively, the buffer utilization can be determined by monitoring the arrival rate of the packets.

In operation, the control unit 25 applies a pre-determined delay to the first packet of a talk-spurt detected by packet analyzer 24. The control unit 25 then delays subsequent packets by an amount appropriate to produce a constant play-out rate to the speech play-out buffer 21. If the minimum number of packets in the buffer is large (i.e., the buffer never becomes close to under-flowing), the control unit 25 slowly reduces the build-out delay. If packets arrive late, (i.e., the buffer risks under-flowing), the build-out delay is increased in order to minimize packet loss. Adjustment of the build-out delay can be determined in a number of ways, such as monitoring the minimum, maximum or average utilization of the buffer. Alternatively, it is possible to monitor the time a packet spends in the buffer.

Preferably, the delay adjustment is done during speech silence. Normally, the duration of gaps between spoken words is precisely replicated by sending a silence duration value in the first packet of each new talk spurt, which can be detected by the packet analyzer 24. when the build-out delay has to be increased, the silence duration is artificially increased. The result is a larger build-out delay during the next talk spurt. When the build-out delay has to be decreased, the silence duration is artificially decreased. The result is a shorter build-out delay during the next talk spurt.

Although the preferred embodiment has been described with reference to audio signal, the invention may also be

- 7 -

applied to video transmission. In this case video packets carry the video data, and the speech reconstituter is replaced by a video reconstituter, which operates in an analogous manner. Indeed the invention is applicable to
5 any digitized physical signal that is transmitted in packetized format and then reconstituted at the far end. The video implementation looks the same as the implementation shown in the drawings with the word "video" substituted for the word "speech" throughout.

- 8 -

Claims:

1. A method of playing out packets received through a packet network subject to variable transmission delays, characterized in that it comprises the steps of:
 - 5 a) receiving incoming packets in a buffer;
 - b) applying a delay to the first packet of a sequence of packets;
 - c) applying a variable delay to subsequent packets of the sequence to produce an appropriate constant play-
10 out rate of said packets to reproduce the desired output;
 - d) monitoring the utilization of said buffer; and
 - e) adjusting the delay applied to the first packet of a following sequence of packets to maintain said
15 buffer utilization within desired limits to minimize the risk of said buffer underflowing or overflowing.
2. A method as claimed in claim 1, characterized in that in step d the fill level of said buffer is monitored.
3. A method as claimed in claim 1, characterized in
20 that in step d the dwell time of said packets in said buffer is monitored.
4. A method as claimed in claim 1, characterized in that said packets are voice or audio packets.
5. A method as claimed in any of claims 1 to 4,
25 characterized in that each said sequence represents a signal spurt.
6. A method as claimed in claim 5, characterized in that said delay adjustment is carried out during signal activity in the gaps between signal spurts.
- 30 7. A method as claimed in claim 5, characterized in that a signal inactivity duration value is inserted in the first packet of each spurt.

- 9 -

8. A method as claimed in claim 1, characterized in that said packets are video packets.
9. An apparatus for playing out packets received through a network subject to variable transmission delays, comprising:
- a) a buffer for receiving incoming packets;
 - b) a signal reconstituter for receiving said packets from said buffer and reconstituting signal samples therefrom;
 - 10 c) a variable delay unit for applying a delay to the incoming packets;
 - d) a control unit for controlling said delay to apply a first delay to an incoming sequence of packets and a variable delay to subsequent packets of the
 - 15 sequence so as to produce an appropriate constant play-out rate to said buffer;
 - e) means for monitoring the utilization of said buffer; and
 - f) means for adjusting said first delay applied to
 - 20 the packets of a following sequence of packets to maintain said buffer utilization within desired limits to minimize the risk of said buffer underflowing or overflowing.
10. An apparatus as claimed in claim 9, characterized in that said means for monitoring the utilization of said
- 25 buffer comprises a buffer fill level monitor.
11. An apparatus as claimed in claim 9, characterized in that said means for monitoring the utilization of said buffer comprises a monitor determining the amount of time
- 30 the packets spend in the buffer.
12. An apparatus as claimed in claim 9, characterized in that it further comprises a packet analyzer for detecting the start of a signal spurt.

- 10 -

13. An apparatus as claimed in claim 7, characterized in that said delay adjustment is carried out during the gaps between signals to be transmitted.
14. An apparatus as claimed in claim 9, characterized in that said packets are voice or audio packets.
- 5 15. An apparatus as claimed in claim 9, characterized in that said packets are video packets.

1/2

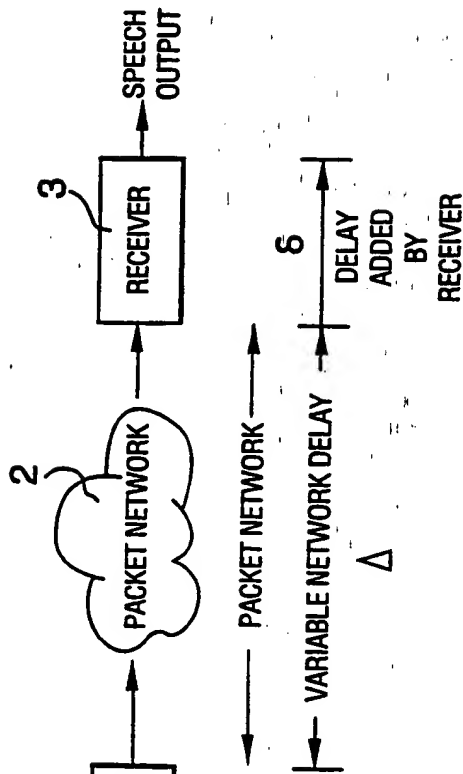


FIG. 1

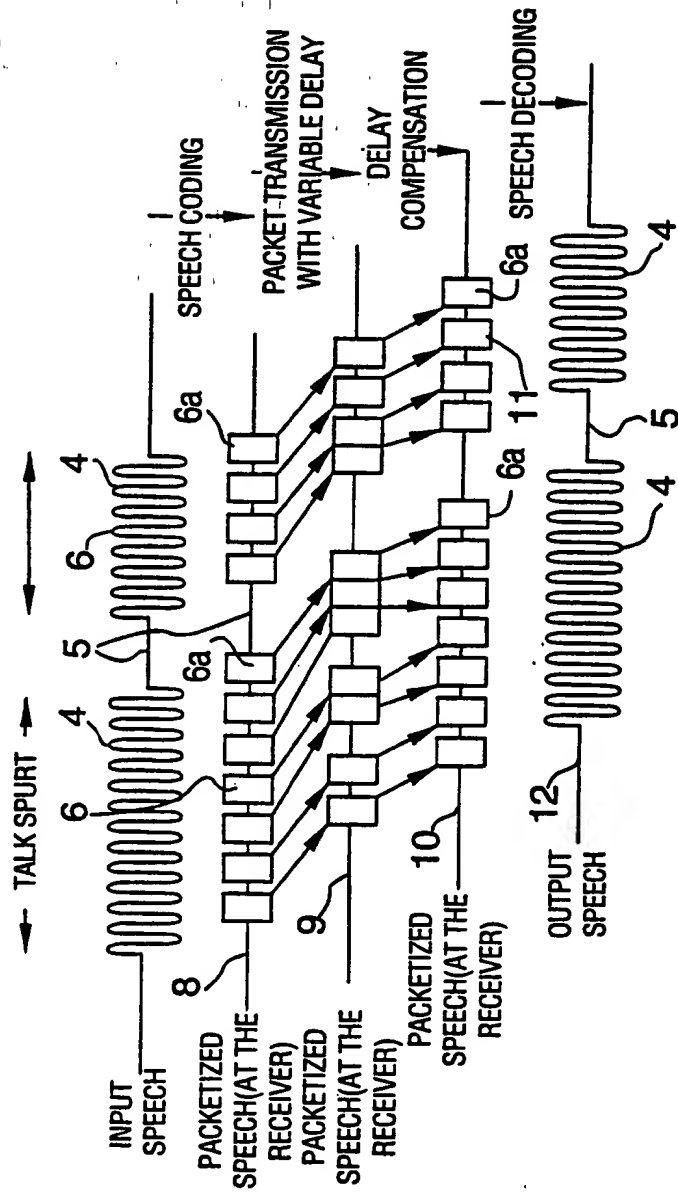


FIG. 2

SUBSTITUTE SHEET (RULE 26)

2/2

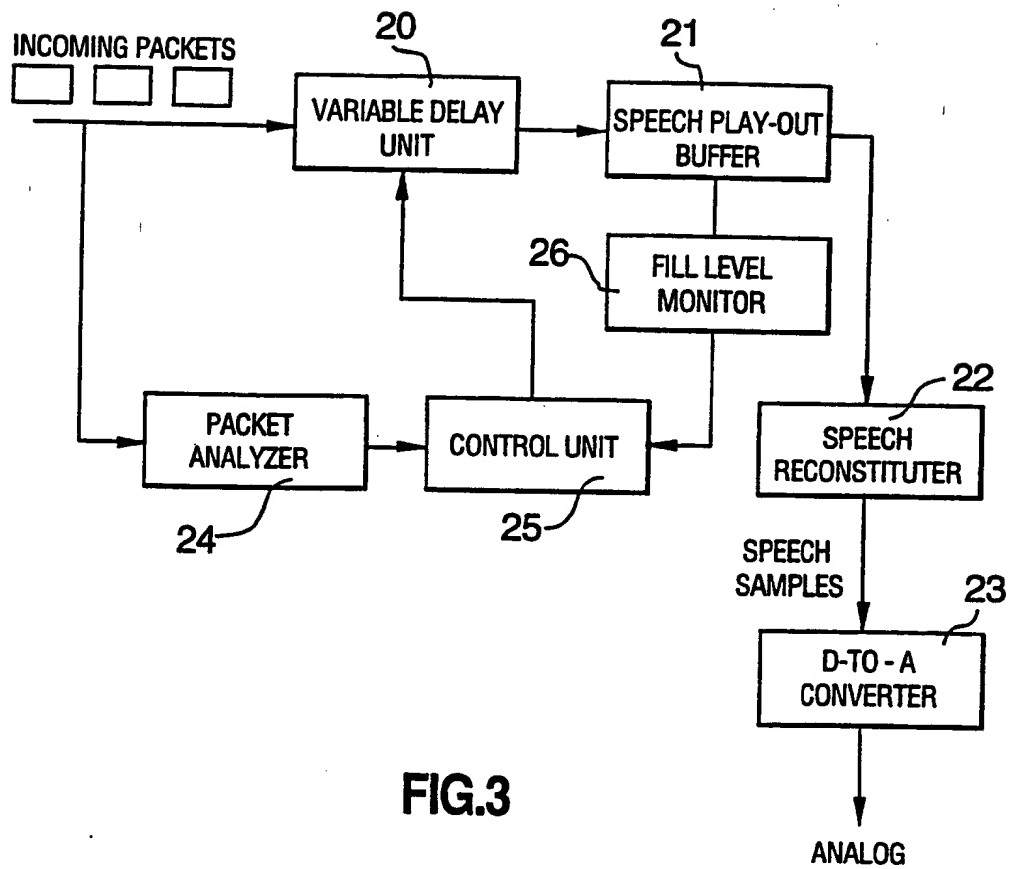


FIG.3

SUBSTITUTE SHEET (RULE 26)

INTERNATIONAL SEARCH REPORT

National Application No

PCT/CA 95/00062

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q11/04 H04J3/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04Q H04J H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, DEC. 1983, USA, vol. SAC-1, no. 6, December 1983 ISSN 0733-8716, pages 1022-1028, MONTGOMERY W A 'Techniques for packet voice synchronization' see page 1022, right column, paragraph 3 - page 1023, left column, paragraph 4	1-6,8
A	see page 1023, right column, paragraph 7 - page 1024, left column, paragraph 1 see page 1024, right column, paragraph 3 see page 1026, left column, paragraph 6 - page 1027, right column, paragraph 1; figures 1,5,6 --- -/--	9-15



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

18 May 1995

Date of mailing of the international search report

98.06.95

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+ 31-70) 340-3016

Authorized officer

Pieper, T

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No
PCT/CA 95/00062

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-130431	09-01-85	US-A- 4538259	27-08-85
		JP-C- 1728158	19-01-93
		JP-B- 4011059	27-02-92
		JP-A- 60027255	12-02-85
<hr/>			
WO-A-8701254	26-02-87	AU-B- 604650	03-01-91
		AU-A- 6330986	10-03-87
		AU-B- 635805	01-04-93
		AU-A- 6937791	11-04-91
		CA-A- 1273697	04-09-90
		CA-A- 1334685	07-03-95
		DE-A- 3688595	22-07-93
		EP-A, B 0235257	09-09-87
		JP-T- 63500697	10-03-88
		KR-B- 9400395	19-01-94
		US-A- 4782485	01-11-88
		US-A- 5018136	21-05-91
<hr/>			

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 95/00062

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 130 431 (IBM) 9 January 1985 see page 11, line 16 - page 12, line 7 see page 14, line 31 - page 16, line 20; figures 2,3 ---	1,2,4,5, 9,10,14
A	WO,A,87 01254 (REPUBLIC TELCOM SYSTEMS) 26 February 1987 see page 7, line 6 - line 11 see page 19, line 31 - page 21, line 1; figure 4 ---	1,9
A	EBU REVIEW, TECHNICAL, JUNE 1991, BELGIUM, no. 247, June 1991 ISSN 0379-7155, pages 124-131, XP 000228454 ASSMUS U ET AL 'High-quality video and audio signal transmission in a broadband ISDN based on ATD' see abstract see page 128, paragraph 6.1; figure 6 -----	1,2,4,5, 8-10,14, 15